DOES BLACK HOLE SPIN PLAY A KEY ROLE IN THE FSRQ/BL LAC DICHOTOMY?

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It is believed that jets emerging from blazars (flat spectrum radio quasars (FSRQs) and BL Lacs) are almost aligned to the line-of-sight. BL Lacs usually exhibit lower luminosity and harder power law spectra at gamma-ray energies than FSRQs. It was argued previously that the difference in accretion rates is mainly responsible for the large observed luminosity mismatch between them. However, when intrinsic luminosities are derived by correcting for beaming effects, this mismatch is significantly reduced. We show that spin plays an important role to reveal the dichotomy of luminosity distributions between BL Lacs and FSRQs, suggesting BL Lacs to be low luminous and slow rotators compared to FSRQs.

Keywords: black hole physics — BL Lacertae objects: general — quasars: general — gravitation — relativity

1. Introduction

Blazars are the extragalactic radio-loud sources identified in gamma-ray catalogs of EGRET and Fermi. They are divided by two classes: BL Lacertae (BL Lac) and Flat Spectrum Radio Quasar (FSRQ). While the later class shows steep spectra in high energy and higher luminosity, the former one exhibits flat γ-ray photon spectral index with a lower luminosity. Ghisellini et al.[1] argued that the luminosity difference arises due to difference in accretion rates between the respective systems. However, based on MHD simulations, Tchekhovskoy et al.[2] showed that luminosity dichotomy between radio-loud and radio-quiet Active Galactic Nuclei (AGNs) arises due to the spin difference between the respective sources.

It has been shown by this author[3,4] that the outflow power and then luminosity of a black hole system increases with increasing spin of the black hole. Based on this theory, below we establish that the dichotomy between BL Lacs and FSRQs is due to their spin difference. Moreover, we show that the incorporating idea of difference in accretion rates between BL Lacs and FSRQs gives misleading results.

2. Basic data and unbeamed luminosities

We consider 11 months Fermi data[5] having 281 FSRQs and 291 BL Lacs with measured redshift (z). Further, from radio observations[6] we compute average Doppler beaming factor $\delta \sim 20.6 \pm 8.4$ of sources. As BL Lacs and FSRQs are subclasses of FR I and FR II galaxies respectively, when the jet to line-of-sight angles are very small and hence the jets appear very beamed, we can relate observed and intrinsic luminosities as[7]

$$L_{\rm observed} = L_{\rm intrinsic}\, \delta^{m+n}, \tag{1}$$

where $m = 2$ and 3 for continuous and discrete jets respectively, $n = \alpha_\gamma$ and $2\alpha_\gamma + 1$ for emissions due to synchrotron self-Comptonization (SSC) and external Comptonization (EC) processes respectively, α_γ is the energy spectral index. Note that $L_{\rm intrinsic}$ is the quantity produced at the base of jet, before it was beamed.[3] Hence, this can be obtained, by knowing $L_{\rm observed}$ and δ from observed data. On the other hand, $L_{\rm intrinsic}$ can be computed independently from the model in Ref. 3. Figure 1a shows FSRQs exhibiting on average three orders of magnitude higher luminosity and larger photon spectral index than those of BL Lacs. Moreover, FSRQs show strong emission lines, whereas BL Lacs do not. However, Fig. 1b shows that the difference between respective unbeamed/intrinsic luminosities, from eqn. (1), is very small. Note that $L_{\rm intrinsic}$ is determined solely by the parameters of disk-outflow coupled dynamics, e.g. accretion rate, mass and spin of the black hole. From Refs. 3,4, it can be shown that outflow powers and then $L_{\rm intrinsic}$s between FSRQs and BL Lacs[1] are significantly different, if their accretion rates are also significantly different, as was suggested earlier,[1] which contradicts data. We propose that the difference in spin (a) of the underlying black holes governs any small difference in $L_{\rm intrinsic}$s between FSRQs and BL Lacs.

3. Explaining intrinsic dichotomy via spin difference

It is found[3,4] that the power of astrophysical jets increases with increasing spin of central object. We propose a fitting function for jet power

$$P_j = 10^{Aa^3+Ba^2+Ca+D}, \tag{2}$$

where $A = 2.87\pm0.26$, $B = -4.08\pm0.40$, $C = 2.88\pm0.17$ and $D = 41.53\pm0.02$. As P_j is calculated in the frame of disk-outflow coupled system, we assume in the first approximation that it is proportional to $L_{\rm intrinsic}$ such that

$$\frac{P_{j,FSRQ}}{P_{j,BLLac}} = \frac{L_{\rm unbeamed,FSRQ}}{L_{\rm unbeamed,BLLac}}, \tag{3}$$

but not the observed luminosity. Now if we know the spin of BL Lac (a_{BL}), then from eqn. (3) the spin of FSRQ (a_{FSRQ}) can be obtained, when R.H.S. of eqn. (3) is known from observation and denominator and numerator of L.H.S. are respectively supplied and computed based on eqn. (2). Figure 1c shows the variation of P_j with a. Now being radio-loud AGNs, blazars are expected to be harboring fast rotating black holes than the radio quiet AGNs[2] and hence $a \geq 0.5$ in blazars (and hence of BL Lacs, which are expected to have relatively lower luminosity and hence lower a than FSRQs). Similarly, maximum possible a corresponds to FSRQs. Based on this idea, Fig. 1d argues for a range of a_{FSRQ} for a given range of a_{BL} in accordance with the dichotomy in luminosities in Fig. 1b.

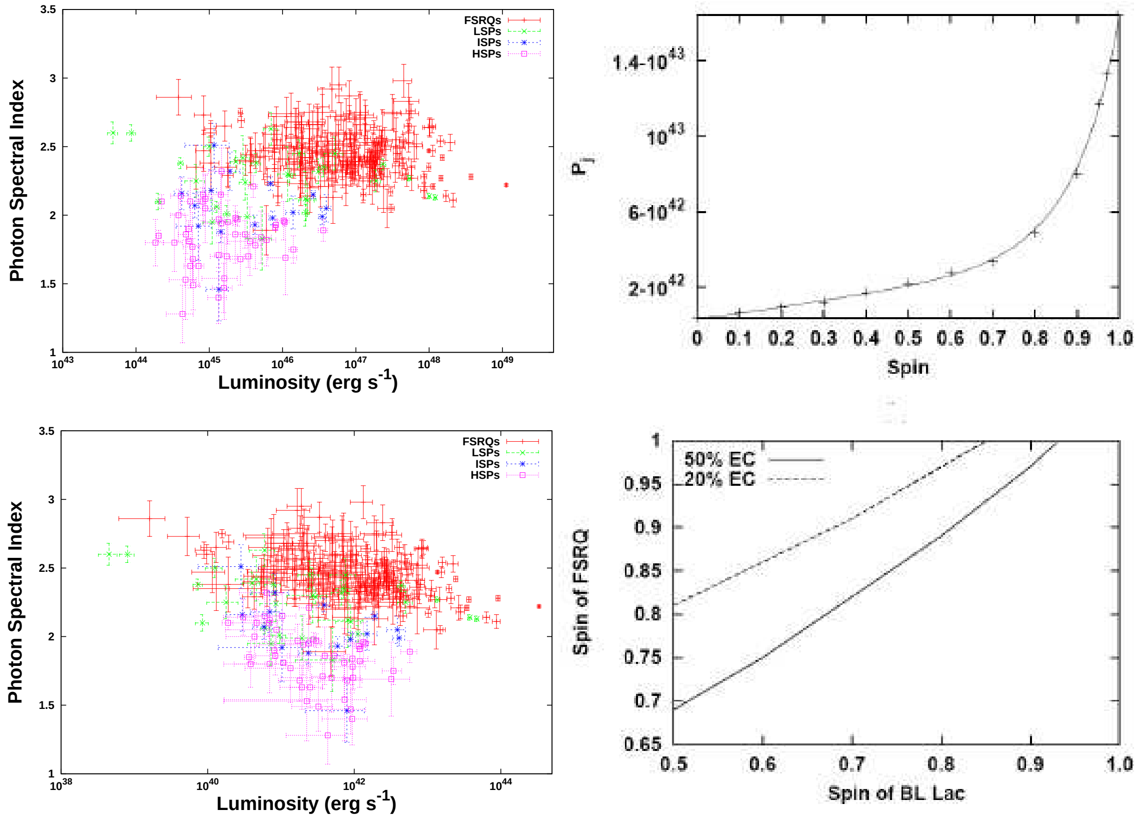

Fig. 1. Upper-Left (a): Observed luminosities and spectral indices for FSRQs (red points) and BL Lacs (green, blue and violet points). Lower-left (b): Same as in (a), except intrinsic luminosities are plotted; 50% SSC and 50% EC are chosen for FSRQs. Upper-right (c): Total mechanical outflow power as a function of black hole's spin, when solid line represents the fitting function given by equation (2). Lower-right (d): The values of FSRQ spin for a range of BL Lac spin.

4. Conclusions

The observed dichotomy between BL Lacs and FSRQs is due to difference in the underlying spins of black holes. We propose $a_{FSRQ} > a_{BL}$, which is consistent with their difference in $L_{\rm intrinsic}$s. The small difference in $L_{\rm intrinsic}$s further gets amplified due to their different emission mechanisms and beaming effects, which then leads to large difference in $L_{\rm observed}$s. For further details, see Ref. 8.

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